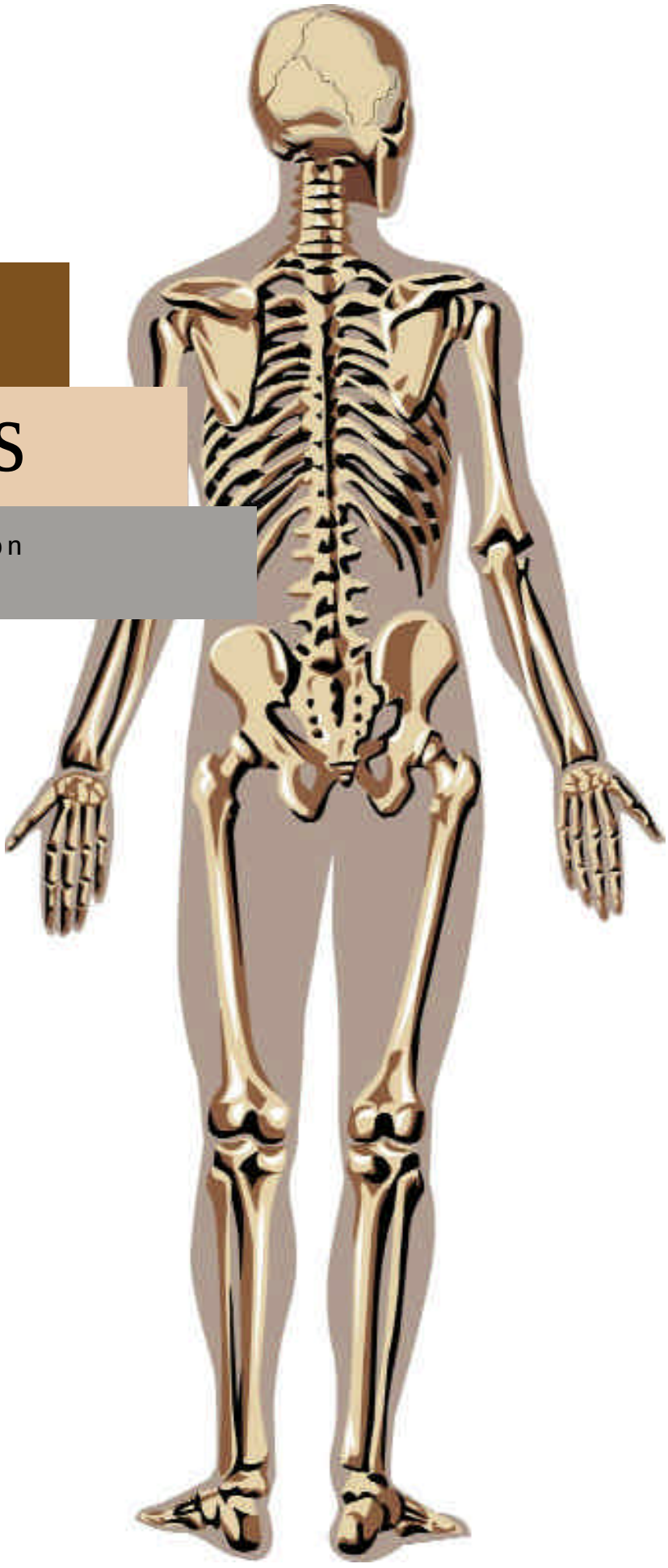
Bag of Bones

Bone Loss During Long Duration Spaceflight



overview

On Earth, healthy bones are necessary for support, movement, and general good health. In space, the lack of gravity can affect how bones are built and, as a result, how they work once an astronaut has returned to Earth. It is essential to future space flight activities to understand why these changes happen and the effects of these changes so that our astronauts remain healthy. What we learn about the effects of spaceflight on bone also helps us maintain healthy bones and bodies on Earth.

Objectives
The students will be able to explain the functions of bone, identify the effects of microgravity on bone and describe why healthy bones are important in space and on Earth.

National Science Standards
Science as Inquiry
Life Science

National Mathematics Standards
Mathematics as reasoning
Mathematical connections
Computation and estimation

Materials Needed
Corn puff cereal (approx. 4.5 oz. Per group)
Snack size zip locking plastic bags (6 5/8 inch x 3 ¼ inch) 5 per group

Note: Make sure to use the small, snack-sized bags; the large ones hold too much cereal to count in a reasonable amount of time.
Heavy books- one per group
Student Activity Guide- one per student
Broom and dustpan (for clean-up)

background

Life in the microgravity environment of space brings many changes to the human body. The loss of bone and muscle mass, change in cardiac performance, variation in behavior, and body-wide alterations initiated by a
changing nervous system are some of the most apparent and potentially detrimental effects of microgravity. Changes to bone are particularly noticeable because they affect an astronaut's ability to move and walk upon return to Earth's gravity.

Structure and Function of Bone
Bone is a living tissue. It is dynamic, responsive to disease and injury, and self-repairing. Bone has both an organic component and an inorganic component. The organic component is composed mainly of collagen, long chains of protein that intertwine in flexible, elastic fibers. Hydroxyapatite, the inorganic component, is a calcium-rich mineral that stiffens and strengthens the collagen. Together, the interwoven organic and inorganic components of bone create a sturdy yet flexible skeletal structure.

The body is constantly breaking down old bone, and replacing it with new bone. Bone is formed by cells called osteoblasts. These cells lay down new mineral along the surface of bone. Osteoclasts, large multinucleate cells, breaks down old bone, and are in part responsible for releasing calcium into the bloodstream. In a healthy individual on Earth, bone is formed at the same rate at which it is broken down, so there is never an overall loss of bone mass. This process changes as a person grows older, or enters microgravity for an extended period of time.

On Earth, bones perform four basic functions:
· Mechanical support: The skeleton supports soft tissue and the body's weight. Many bones also act as levers for muscles, enabling movement.
· Storage of essential nutrients: Bone stores much of the calcium received from the diet. The calcium is stored in hydroxapatite (the principal bone salt which provides the compressional strength of vertebrate bone). Between meals, the body maintains a constant concentration of calcium by absorbing it from bone and releasing it into the bloodstream. This constant calcium level in the bloodstream allows proper neural, muscular, and endocrine (hormone) functioning, as well as other cellular activities (e.g., blood clotting). From the bloodstream, the calcium is taken up by different organs and systems of the body. When the body absorbs too much calcium from bones the skeleton can become thin and weak.
Bone is also a good source of phosphate, hydrogen, potassium, and magnesium. Like calcium, these minerals are used by many systems of the body for a wide range of purposes.

· Production of blood: In addition to essential minerals, bone is also the storage site of marrow. Marrow is important for the formation and development of red and white blood cells and platelets.
· Protection: The skeleton houses and protects the brain, spinal column, and nerves. Many bones, especially the ribs, also protect the internal organs.

Bone and Microgravity

Some of the processes and functions of bones change after the astronaut has lived in microgravity for several days. In space, the amount of weight that bones must support is reduced to almost zero. At the same time, many bones that aid in movement are no longer subjected to the same stresses that they are subjected to on Earth. Over time, calcium normally stored in the bones is broken down and released into the bloodstream. The high amount of calcium found in astronaut's blood during spaceflight (much higher than on Earth) reflects the decrease in bone density, or bone mass. This drop in density, known as disuse osteoporosis , leaves bone weak and less able to support the body's weight and movement upon return to Earth, putting the astronaut at a higher risk or fracture.

This bone loss begins within the first few days in space. The most severs loss occurs between the second and fifth months in space, although the process continues throughout the entire time spent in microgravity. Extended stays on Mir have resulted in losses of bone mass of as much as 20%. Astronauts regain most of their bone mass in the months following their return from space, but not all of it.

The exact mechanism that causes the loss of calcium in microgravity is unknown. Many scientists believe that microgravity somehow causes bone to break down at a much faster rate than it is built up. However, the exact trigger for this rate change has not been found. Researchers are currently pursuing multiple lines of research, including hormone level, diet, and exercise, in order to determine exactly what causes- and may control or prevent-osteoporosis during space flight.

Another type of osteoporosis is a problem on Earth. As we grow older, the body begins to absorb bone much faster than it produces new bone. This leads to a lowered bone density, the same effect that microgravity has on astronauts. As a result, bones become more fragile and are more susceptible to fractures, especially in the hip, spine, and wrist. In many cases, people do not know that they have

osteoporosis until their bones become so weak that an accidental bump or fall causes a fracture.

Just as astronauts eat a careful diet and get plenty of special exercise in space to prevent disuse osteoporosis, steps can be taken to prevent osteoporosis on Earth. A balanced diet rich in calcium and vitamin D, exercise, a lifestyle free of smoking and alcohol, bone density testing, and medication all prevent or alleviate osteoporosis.

Activity

The students will investigate bone loss and the effects that it may have on astronauts and people on Earth. To do this, plastic bags and cereal will be used to demonstrate bones. Each plastic bag will represent a bone, and the cereal inside the bone will represent the calcium and cells that make the bone strong. Removing cereal from some of the bags will simulate a bone that has lost some of its mass.

In order to expedite the experiment, students should work in-groups of four; the group can work on bag 1 together, then each student will be responsible for one additional bag.
Note about cereal smashing:
Some of the cereal has natural holes in it. Students should examine cereal carefully before smashing it, so that they have a reference point when counting unaffected pieces. In addition, one student should be responsible for smashing all of the bags, so that the amount of force will be the same on all bags. Students should keep in mind that cereal pieces that have dust on them from other smashed pieces, or only a tiny flake taken off should not be counted as "affected".

After the students have completed the activity, results should be shared with the class.

If some group results did not come out as expected (i.e., density did not drop), discus possible reason for this.

bags of bone

Discussion
Good nutrition is essential for healthy bones. What types of minerals help create strong bones? What can be done to help create and maintain healthy bones
Aging and space flight have a similar effect on the human body: both may lead to osteoporosis, or a loss of bone mass. Osteoporosis makes bones weak and fragile, which can make it very easy to fracture or break a bone. In fact, many people do not realize that they have osteoporosis until one of their bones fractures after a minor slip or fall. Using every-day baggies and cereal to represent bone, and a heavy textbook to represent an unexpected force (like a bump or a fall), we will see why osteoporosis can cause problems for astronauts-and for people on Earth-if this condition is left untreated.

What you need:
5 snack bags
Cereal
A very heavy book (like a dictionary)
A broom and dustpan (for clean-up)
Permanent marker
Pen or pencil

Things to think about:
Why is it important to have strong, healthy bones?
What will happen if your bones become weak?
What can you do to keep your bones strong?

What to do:
1. Using a permanent marker, label the bags 1-5.

2. Bag 1 will represent a healthy bone on Earth. To build a "bone" you will use pieces of cereal to represent individual units of bone mass. Fill the bag with enough cereal so that the bag is very full and there is very little air in it, but not so full that you cannot close it. Keep track of how many pieces of cereal you put into the bag, and record this on your worksheet as Normal Bone Density. Close the bag, and make sure it is closed tightly-otherwise you may wind up with a very big mess!

3. To represent a bone that has lost mass as a result of spaceflight or aging, you now need to fill each bag with less cereal, or bone mass, than is in Bag 1.
Bag 1: 0% bone loss (normal bone)
Bag 2: 90% of original bone remains; 10% original bone lost
Bag 3: 80% of original bone remains; 20% original bone lost
Bag 4: 65% of original bone remains; 35% original bone lost
Bag 5: 50% of original bone remains; 50% original bone lost
To calculate the amount of cereal you need in Bag 2, figure out what 90% of the Normal Bone Density is. Fill Bag 2 with this amount. This represents a loss of 10% of the bone mass.

Use a similar method to calculate 80%, 65%, and 50% of the Normal Bone Density, and fill Bags 3, 4, and 5 with these amounts. Record the amount of bone left in each bag on your worksheet.

4. Now you are ready to see what the effects of a sudden force may be on weakened bones. Place Bag 1 on a hard surface. Then, quickly and carefully, but forcefully, smash the heavy book onto the bag. Turn the bag over, and smash the book on the other side using the same amount of force. Again using the same amount of force, smash the remaining bags.

5. What happened to your bones? Count the number of unaffected cereal pieces left in each bag, and record this on your worksheet.

6. How much of the bone was unaffected? To calculate this, use this formula:

$$\left[\frac{\text{\# unaffected remaining in the bag}}{\text{original density of the bag}}\right] \times 100$$

Record your values on your worksheet.

7. How much of the bone was affected? To calculate this, subtract the Unaffected Bone value from 100%. Record your values on your worksheet.

Normal Bone Density =_____ pieces of cereal in Bag 1

Density of Bone 2 = 90% of Bag 1 = _____ pieces of cereal

Density of Bone 3 = 80% of Bag 1 = _____ pieces of cereal

Density of Bone 4 = 65% of Bag 1 = _____ pieces of cereal

Density of Bone 2 = 50% of Bag 1 = _____ pieces of cereal

	Before the Experiment	After the Experiment			
Bag	BoneLoss Represented	Density (# of cereal pieces in bag)	# of unaffected	% of bone unaffected	% of bone affected
1	0%				
2	10%				
3	20%				
4	35%				
5	50%				

What happened?

1. What happened as bone density decreased?

2. What prevented some bone from being affected by the sudden force of the book?

3. What do you think would happen if the plastic bag and cereal was a real bone, and a sudden force (like a bump or fall) was applied to the bone(s)?

4. How do you think we can prevent bone loss?